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A KEY, BASED ON SCALES, TO THE FAMILIES OF NATIVE CALIFORNIA FRESHWATER FISHES

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Abstract: Much interdisciplinary interest has been shown with regard to fish scales in addition to their use in fisheries biology. To aid future workers, a key to the scales of the native California freshwater fish families is presented along with photomicrographs of scales from each group.

Introduction

Fish scales have been used in fisheries biology and systematic ichthyology for many years. Within fisheries studies, emphasis has been placed upon the use of scales in age and growth studies (Cable, 1956; Cating, 1954; Chugunova, 1959; Cooper, 1951, 1952; Fry, 1943; Hile, 1936; Hogman, 1970; Jensen and Wise, 1961; Miller, 1955; Phillips, 1948; Rush, 1952; Schuck, 1949; Taylor, 1916; Whitney and Carlander, 1956; Meehean, 1935). Various keys, based upon the morphology of scales, have been published dealing with species identification within families and with the identification of families comprising regional fish faunas (Batts, 1964; Lagler, 1947; Koo, 1962).

Fish scales have been used in palaeontological work (David, 1944, 1946a, 1946b), sediment analysis (Lagler and Vallentyne, 1956; Pennington and Frost, 1961; Soutar and Isaacs, 1969), and archaeology (Follett, 1967a, 1967b; Hubbs and Miller, 1948). Even within fisheries work, scales have been encountered during analysis of the stomach contents of various fishes (Greenfield, Ross, and Deckert, 1970; Kimsey, 1954). Based upon this evidently wide interdisciplinary interest in and use of fish scales, it is felt that a scale-based key to the families of native freshwater fishes of California would be a useful aid.

TABLE 1. *Species examined.*

Species	Source
Thaleichthys pacificus	CAS[1]
Oncorhynchus tshawytscha	UCD[2]
O. kisutch	CAS, UCD
Salmo gairdnerii	UCD
S. g. gairdnerii	UCD
S. g. stonei	UCD
S. g. gilberti	CAS
S. g. aquilarum	CAS
S. clarkii clarkii	CAS
S. c. henshawi	CAS
S. c. seleniris	CAS
S. aguabonita aguabonita	CAS
S. a. whitei	CAS
Salvelinus malma parkei	CAS
Prosopium williamsoni	CAS
Xyrauchen texanus	CAS
Catostomus luxatus	CAS
C. platyrhynchus	CAS
C. santaanae	CAS
C. rimiculus	CAS
C. latipinnis	CAS
C. occidentalis occidentalis	UCD
C. o. humboldtianus	CAS
C. mniotiltus	CAS
C. tahoensis	CAS
Rhinichthys osculus klamathensis	CAS
Mylopharodon conocephalus	CAS, UCD
Orthodon microlepidotus	UCD
Pogonichthys macrolepidotus	UCD
Lavinia exilicauda exilicauda	UCD
L. e. harengus	CAS
Ptychocheilus grandis	UCD
Hesperoleucas symmetricus symmetricus	UCD
H. s. subditus	CAS
H. s. venustus	CAS, UCD
H. navarroensis	CAS
H. parvipinnis	CAS
Gila bicolor bicolor	CAS
G. b. obesa	CAS, UCD
G. b. pectinifera	CAS
G. mohavensis	CAS
G. crassicauda	CAS
G. orcutti	CAS

[1] CAS = specimens from California Academy of Sciences, San Francisco.
[2] UCD = specimens from the author's personal collection, presently at University of California, Davis.

Table 1. (*continued*)

Species	Source
G. elegans	CAS
Richardsonius balteatus egregius	CAS
Cyprinodon macularius californiensis	CAS
C. nevadensis nevadensis	CAS
C. n. calidae	CAS
C. n. shoshone	CAS
C. salinus	CAS
Fundulus parvipinnis	CAS
Mugil cephalis	CAS
Archoplites interruptus	UCD
Hysterocarpus traskii	CAS, UCD

For the purposes of this paper, native freshwater fishes will refer to those fishes which occur exclusively in freshwater or spend a significant portion of their life-cycle in freshwater and which occurred in California prior to the known introduction of exotic species during and after the nineteenth century (Kimsey and Fisk, 1960; Shapovalov, Dill, and Cordone, 1959; Walford, 1931). The only exception has been the inclusion of the Mugilidae because of their importance in the Colorado River.

Methods and Materials

The scales studied come from 54 species of native fishes (table 1) and represent specimens collected by the author or by members of the California Department of Fish and Game, and specimens from the California Academy of

Table 2. *Scale sampling locations.*

A. Row anterior to dorsal fin.
B. Right side, below dorsal fin, above lateral line.
C. Left side, below dorsal fin, above lateral line.
D. Right side, below dorsal fin, below lateral line.
E. Left side, below dorsal fin, below lateral line.
F. Right side, caudal penduncle, above lateral line.
G. Left side, caudal penduncle, above lateral line.
H. Right side, caudal penduncle, below lateral line.
I. Left side, caudal penduncle, below lateral line.
J. Row posterior to dorsal fin.

TABLE 3. *Scale characteristics of California freshwater fish families.*

Family	Ctenoid Scales	Cycloid Scales	Scutes	Neither
Petromyzonidae				X
Acipenseridae			X	
Osmeridae		X		
Salmonidae		X		
Catostomidae		X		
Cyprinidae		X		
Gasterosteidae			X	
Cyprinodontidae	X	X[3]		
Mugilidae	X			
Centrarchidae	X			
Embiotocidae		X[3]		
Cottidae				X

[3] Scales of these families, while being cycloid, should be oriented as shown for ctenoid scales in figure 1 b.

Sciences, San Francisco. Table III indicates the general scale characteristics of the fishes in this study.

The fish were sampled for scales from ten different body locations (table 2) on the author's specimens. For reasons of future use, the specimens from the California Acadamy of Sciences could only be sampled from six locations on the right-hand side of the fish. Wherever possible, samples were taken from several individuals of different sizes within a species in order to allow for ontogenetic variations. All scale samples were mounted in glycerine jelly on microscope slides (Weesner, 1960) and examined under a dissecting microscope at between ten and thirty magnifications.

DEFINITIONS

The terms used here to describe the surface features of scales are taken from Lagler (1947, pp. 150–151) and are illustrated in figure 1.

Circuli — "Elevated markings on the outer surface; usually appearing as lines which more or less follow the outline shape of the scale."

Focus — "First part of scale to appear in growth; often central."

Radii — "Grooves, usually more or less radiating from focus to one or more margins."

Primary Radii — "Radii that extend from focus to margin."

Secondary Radii — "Radii that begin outward from, not at, focus."

Ctenii — "Tooth-like structures on posterior portion of scale."

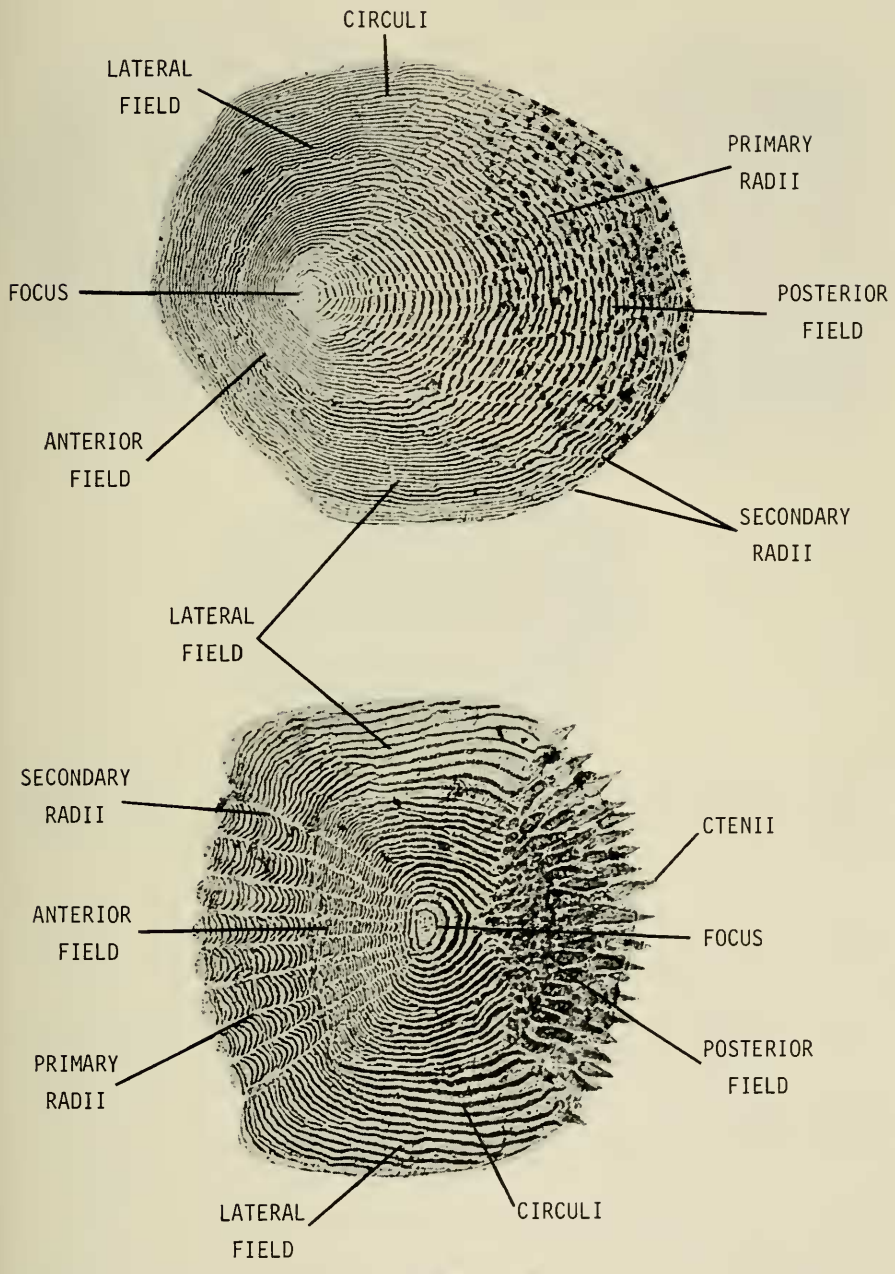

FIGURE 1. Top. Cycloid Scale. *Cyprinidae. Mylopharodon conocephalus.* UCD 5040 C. Bottom. Ctenoid Scale. Centrarchidae. *Archoplites interruptus.* UCD 5021 E.

FIGURE 2. a. Cyprinodontidae. *Cyprinodon macularius californiensis*. UCD 5063 G. b. Centrarchidae. *Archoplites interruptus*. UCD 5021 E. c. Mugilidae. *Mugil cephalus*. UCD 5056 I.

Fields — "Areas of the outer surface of the scale, either real as delimited by angulation of the ridges (circuli) at levels of the four principal corners or imaginary if the corners or configuration of the circuli are wanting. Adjectives of direction applied to fields are based on their positions when the scales are normally situated on the side of the fish."

Anterior Field — "Bounded by imaginary lines connecting the anterolateral corners, or their equivalent points on scales which are rounded (dorsal and ventral) with the focus."

Posterior Field — "Bounded by imaginary lines connecting the posterolateral corners (dorsal and ventral) with the focus."

Lateral Fields — "Dorsal and ventral fields remaining after delimitation of anterior and posterior ones."

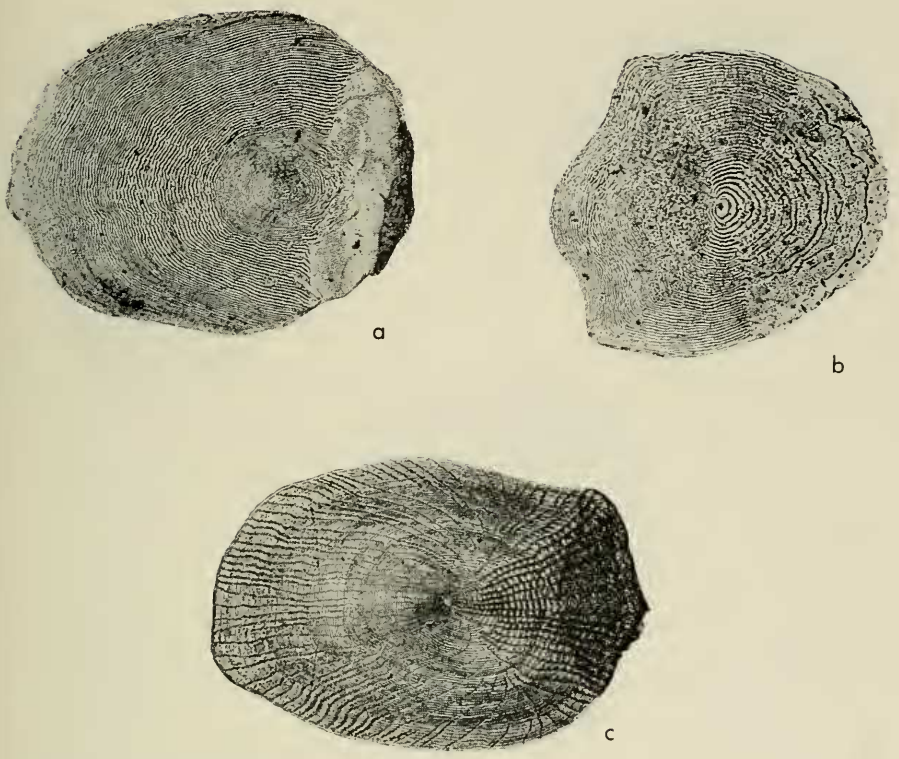

Figure 3. a. Salmonidae. *Salmo gairdnerii gairdnerii*. UCD 5002 D. b. Salmonidae. *Prosopium williamsoni*. UCD 5016 C. c. Catostomidae. *Catostomus occidentalis occidentalis*. UCD 5026 C.

Scale-based Key to the Families of California Freshwater Fishes

The following is a key to the family level with the exception of *Prosopium williamsoni* which is identified to species.

The Cyprinodontidae are characterized by both ctenoid and cycloid scales in the same individual. Lagler (1947, pp. 156–157) classified the Cyprinodontidae of the Great Lakes as having cycloid scales and the same appears true of the genus *Fundulus* in California. However, the other members of this family may also possess ctenoid scales (Lagler, Bardach, and Miller, 1962, p. 114). For this reason the key identifies this family twice, once on the basis of ctenoid scales and again on the basis of cycloid scales. This same case appears true of the Centrarchidae (Lagler, Bardach, and Miller, 1962, p. 114). Based upon data from my collections, however, I find cycloid scales to occur only once in 32 samples and

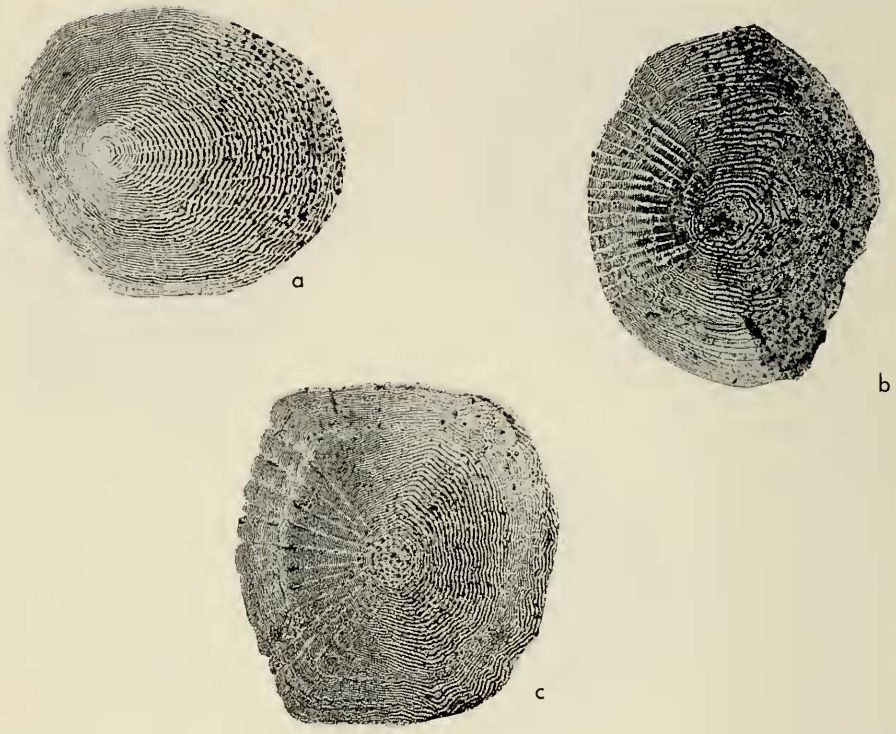

FIGURE 4. a. Cyprinidae. *Mylopharodon conocephalus*. UCD 5040 C. b. Cyprinodontidae. *Cyprinodon macularius californiensis*. UCD 5063 A. c. Embiotocidae. *Hysterocarpus traskii*. UCD 5099 C.

then only from restricted areas of the body in centrarchids (table 2, A). This is a rather low frequency and if one considers the total number of scales over a fish's body, it appears that occurrence of cycloid scales in *Archoplites interruptus* will be even more rare. I agree, therefore, that "These fishes may still be considered as predominantly ctenoid in their squamation but the degree and extent of development of the ctenii varies from place to place on the body" (Lagler, Bardach, and Miller, 1962, p. 114). In the rare event that a cycloid scale from this family should present itself in isolation it will key out as representing the Embiotocidae instead of the Centrarchidae.

Figures 2, 3, and 4 illustrate each of the families or species separated by the key. Each illustration is oriented with the anterior field to the observer's left.

1. a) Ctenii present on posterior field 2
   b) Ctenii absent on posterior field 4
2. a) Ctenii numerous and evenly spaced 3

b) Ctenii not numerous and irregularly spaced ..... Cyprinodontidae (figure 2, a)

3. a) Radii converge toward focus ..... Centrarchidae (specifically *Archoplites interruptus*; figure 2, b)

b) Radii roughly parallel ..... Mugilidae (specifically *Mugil cephalus*; figure 2, c)

4. a) Scale cycloid without radii 5

b) Scale cycloid with radii 6

5. a) Scale with anterior and posterior fields only or without fields ..... Osmeridae and Salmonidae (figure 3, a)

b) Scale with four fields; focus centrally located ..... *Prosopium williamsoni* (figure 3, b)

6. a) Primary radii on both posterior and anterior fields ..... Catostomidae (also includes the cyprinid genera *Rhinichthys* and *Orthodon*; figure 3, c)

b) Primary radii absent on either anterior or posterior field 7

7. a) Primary radii present on anterior field, but absent on posterior field 8

b) Primary radii absent on anterior field, but present on posterior field ..... Cyprinidae (figure 4, a)

8. a) Far fewer circuli in lateral than in anterior field ..... Cyprinodontidae (figure 4, b)

b) Number of circuli in lateral field approximately equal to number in anterior field ..... *Embiotocidae* (specifically *Hysterocarpus traskii*; figure 4, c)

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